

This lesson is part of a larger, comprehensive school garden guide called **Minnesota School Gardens: A Guide to Gardening and Plant Science** developed by Minnesota Agriculture in the Classroom in 2013. The entire guide is available at [www.mda.state.mn.us/maitc](http://www.mda.state.mn.us/maitc).



## Grade

High School

### Materials/Preparation

- ☐ Teacher Material A – Degrees of Growth – one per teacher
- ☐ Handout A – Comparing Growth Locations – one per student
- ☐ Assessment A – Comparing Growing Locations – one per student
- ☐ Highlighter
- ☐ Calculators

### optional

- ☐ Computer with spreadsheet software
- ☐ Writing instruments

### Fun Fact

Lettuce is a fairly hardy, cool-weather vegetable that thrives when the average daily temperature is between 60 and 70°F. Lettuce should be planted in early spring or late summer. At high temperatures, growth is stunted and the leaves may become bitter.



# Comparing Growing Locations

## Minnesota K-12 Academic Standards

Math	9.2.4	Represent real world and mathematical situations using equations and inequalities involving linear, quadratic, exponential and nth root functions. Solve equations and inequalities symbolically and graphically. Interpret solutions in the original context.
Science	9.4.1.1	Organisms use the interaction of cellular processes as well as tissues and organ systems to maintain homeostasis.

## Summary/Overview

Students examine several different ways temperature influences plant health and growth. Next they examine two different geographic locations and calculate when fruit would be ready to harvest in both areas.

## Garden Connection

Students use a mathematical formula to calculate the harvest of tomatoes based on average temperatures.

## Background Information

Latitude, elevation, and microclimate zones, such as coastal areas, influence climate, specifically temperature, for a geographic location. A hardiness zone map (page 91) provides information related to temperature ranges of geographic regions. This information is used to determine the species and varieties of plants best suited for an area.



Plants may be classified into two general categories based on temperature requirements. Cool-season plants can survive mild frost and tolerate cool spring and fall temperatures. Warm-season plants are typically killed by frost and require warm temperatures to grow and thrive.

Plant growth and temperature have a direct relationship. As temperature increases, plant growth increases and as temperature decreases, plant growth decreases. Plants require a specific amount of time exposed to a specific threshold of temperature in order to initiate flowering. The requirement is met by accumulating Growing Degree Days (GDD).

Growing Degree Days (GDD) are units of exposure to adequate temperatures required for plant growth. To calculate GDD subtract the base temperature for a specific plant from the average daily temperature. The base temperature is the minimum temperature requirement a plant needs to grow.

For example, the base temperature for tomatoes is 50 degrees Fahrenheit. If the high is 69 and the low is 44, the average daily temperature is 56.5. So the average temperature, 56.5 minus the base temperature is 6.5 GDD.

Objectives

- Define growing degree days.
- Calculate estimated plant maturity dates using growing degree-days in two different geographical locations.
- Compare and contrast cool-season and warm-season crops.
- Explain the relationship between temperature and plant growth.

Procedure

Interest Approach

Discuss why certain crops are grown in certain parts of the country. Examples: oranges in Florida, potatoes in Idaho, peaches in Missouri, and apples in Washington. Explain that this lesson gives students a better understanding of how climate influences crop production.

Summary of Content and Teaching Strategies

Present and discuss information on Teacher Material A. Students write down the formula for Growing Degree Days (GDD) in their notes. If desired, use the first three dates for each location on Handout A as example problems.

Provide students with copies of Handout A. Students will need to refer to their notes from Teacher Material A to retrieve the correct formula for calculating Growing Degree Days (GDD). For teacher reference, the following is the correct formula.

Remember, if the average daily temperature is below the base temperature requirement, the GDD units for that day are zero. Negative numbers always equal zero in this calculation.

Students compare two location’s growing seasons by calculating the GDD unit accumulation. Data is provided to the students including the minimum, maximum, and average daily temperatures for May 1 through September 30. On Handout A, students will keep a running total of GDD units until they reach the 2100 requirement for tomato fruit production.

An alternative to calculating the GDD by hand is to prepare a spreadsheet with the correct formulas to calculate for you. If desired, instruct students on proper use of spreadsheet software and provide the correct formulas to students.



$$\frac{\text{Daily High Temperature} + \text{Daily Low Temperature}}{2} - \text{Base Temperature Requirement} = \text{GDD Units}$$



Please note the values in Table 1 are provided for daily GDD units rather than a running total. This format assists you with helping students determine errors in their calculations.

## Table 1. Comparison Temperature Data

Crookston, MN

Plains, GA

Date	Min	Max	Ave	Daily GDD	Min	Max	Ave	Daily GDD
1-May	32	65	48.5	0	56	91	73.5	23.5
2-May	44	69	56.5	6.5	63	88	75.5	25.5
3-May	54	77	65.5	15.5	59	89	74	24
4-May	49	55	52	2	62	87	74.5	24.5
5-May	51	60	55.5	5.5	68	89	78.5	28.5
6-May	51	68	59.5	9.5	64	81	72.5	22.5
7-May	45	72	58.5	8.5	52	74	63	13
8-May	46	80	63	13	49	83	66	16
9-May	56	84	70	20	60	83	71.5	21.5
10-May	41	68	54.5	4.5	61	88	74.5	24.5
11-May	43	63	53	3	64	90	77	27
12-May	45	75	60	10	64	90	77	27
13-May	57	84	70.5	20.5	65	89	77	27
14-May	40	70	55	5	66	84	75	25
15-May	36	68	52	2	58	86	72	22
16-May	36	63	49.5	0	63	86	74.5	24.5
17-May	57	74	65.5	15.5	63	83	73	23
18-May	43	86	64.5	14.5	57	82	69.5	19.5
19-May	41	58	49.5	0	56	80	68	18
20-May	45	63	54	4	48	86	67	17
21-May	52	80	66	16	52	90	71	21
22-May	54	78	66	16	60	88	74	24
23-May	44	72	58	8	62	86	74	24
24-May	33	51	42	0	60	86	73	23
25-May	43	53	48	0	62	87	74.5	24.5
26-May	36	52	44	0	59	87	73	23
27-May	44	66	55	5	60	85	72.5	22.5
28-May	58	85	71.5	21.5	62	87	74.5	24.5
29-May	53	80	66.5	16.5	63	89	76	26
30-May	53	75	64	14	62	90	76	26
31-May	54	75	64.5	14.5	69	88	78.5	28.5
1-Jun	60	74	67	17	65	84	74.5	24.5
2-Jun	59	78	68.5	18.5	65	74	69.5	19.5
3-Jun	57	81	69	19	61	89	75	25
4-Jun	40	71	55.5	5.5	70	91	80.5	30.5
5-Jun	48	70	59	9	70	89	79.5	29.5
6-Jun	57	70	63.5	13.5	66	91	78.5	28.5
7-Jun	44	70	57	7	73	92	82.5	32.5
8-Jun	52	74	63	13	72	96	84	34
9-Jun	58	79	68.5	18.5	71	96	83.5	33.5
10-Jun	67	86	76.5	26.5	71	97	84	34
11-Jun	72	90	81	31	73	94	83.5	33.5
12-Jun	65	89	77	27	71	85	78	28
13-Jun	64	71	67.5	17.5	66	86	76	26
14-Jun	63	73	68	18	63	86	74.5	24.5
15-Jun	52	72	62	12	65	85	75	25
16-Jun	61	80	70.5	20.5	65	89	77	27



# Table 1. Comparison Temperature Data

Crookston, MN

Plains, GA

Date	Min	Max	Ave	Daily GDD	Min	Max	Ave	Daily GDD
17-Jun	63	84	73.5	23.5	71	95	83	33
18-Jun	52	72	62	12	71	94	82.5	32.5
19-Jun	57	74	65.5	15.5	71	83	77	27
20-Jun	54	78	66	16	70	90	80	30
21-Jun	56	83	69.5	19.5	69	89	79	29
22-Jun	64	85	74.5	24.5	64	93	78.5	28.5
23-Jun	69	91	80	30	66	97	81.5	31.5
24-Jun	70	87	78.5	28.5	68	95	81.5	31.5
25-Jun	65	89	77	27	73	93	83	33
26-Jun	54	79	66.5	16.5	71	91	81	31
27-Jun	54	63	58.5	8.5	70	93	81.5	31.5
28-Jun	47	70	58.5	8.5	72	95	83.5	33.5
29-Jun	57	75	66	16	72	95	83.5	33.5
30-Jun	65	82	73.5	23.5	72	94	83	33
1-Jul	66	81	73.5	23.5	70	96	83	33
2-Jul	58	87	72.5	22.5	70	86	78	28
3-Jul	61	85	73	23	72	81	76.5	26.5
4-Jul	57	87	72	22	67	86	76.5	26.5
5-Jul	53	82	67.5	17.5	66	88	77	27
6-Jul	65	86	75.5	25.5	69	92	80.5	30.5
7-Jul	64	95	79.5	29.5	73	88	80.5	30.5
8-Jul	57	80	68.5	18.5	72	86	79	29
9-Jul	56	79	67.5	17.5	74	91	82.5	32.5
10-Jul	50	71	60.5	10.5	72	93	82.5	32.5
11-Jul	52	73	62.5	12.5	74	92	83	33
12-Jul	49	75	62	12	73	92	82.5	32.5
13-Jul	56	82	69	19	67	93	80	30
14-Jul	52	76	64	14	71	88	79.5	29.5
15-Jul	58	71	64.5	14.5	71	86	78.5	28.5
16-Jul	59	78	68.5	18.5	68	90	79	29
17-Jul	60	84	72	22	73	91	82	32
18-Jul	55	85	70	20	73	92	82.5	32.5
19-Jul	48	77	62.5	12.5	72	93	82.5	32.5
20-Jul	59	81	70	20	71	95	83	33
21-Jul	65	85	75	25	72	90	81	31
22-Jul	66	88	77	27	68	88	78	28
23-Jul	71	95	83	33	66	87	76.5	26.5
24-Jul	73	89	81	31	66	88	77	27
25-Jul	69	94	81.5	31.5	69	89	79	29
26-Jul	56	83	69.5	19.5	69	93	81	31
27-Jul	52	81	66.5	16.5	72	93	82.5	32.5
28-Jul	52	86	69	19	74	95	84.5	34.5
29-Jul	66	91	78.5	28.5	74	93	83.5	33.5
30-Jul	69	90	79.5	29.5	72	93	82.5	32.5
31-Jul	68	92	80	30	73	91	82	32
1-Aug	58	83	70.5	20.5	72	93	82.5	32.5
2-Aug	49	82	65.5	15.5	69	93	81	31
3-Aug	58	83	70.5	20.5	72	93	82.5	32.5
4-Aug	62	81	71.5	21.5	69	97	83	33
5-Aug	51	85	68	18	75	96	85.5	35.5

Met GA (2125)

# Table 1. Comparison Temperature Data

Crookston, MN

Plains, GA

Date	Min	Max	Ave	Daily GDD	Min	Max	Ave	Daily GDD
6-Aug	58	75	66.5	16.5	76	97	86.5	36.5
7-Aug	60	82	71	21	76	100	88	38
8-Aug	57	76	66.5	16.5	75	101	88	38
9-Aug	64	88	76	26	78	99	88.5	38.5
10-Aug	64	89	76.5	26.5	78	100	89	39
11-Aug	48	86	67	17	76	103	89.5	39.5
12-Aug	54	73	63.5	13.5	74	93	83.5	33.5
13-Aug	56	74	65	15	72	95	83.5	33.5
14-Aug	53	75	64	14	76	98	87	37
15-Aug	46	80	63	13	74	99	86.5	36.5
16-Aug	41	75	58	8	73	98	85.5	35.5
17-Aug	49	72	60.5	10.5	73	98	85.5	35.5
18-Aug	53	74	63.5	13.5	71	93	82	32
19-Aug	56	71	63.5	13.5	72	94	83	33
20-Aug	58	65	61.5	11.5	72	95	83.5	33.5
21-Aug	58	77	67.5	17.5	73	99	86	36
22-Aug	49	85	67	17	78	102	90	40
23-Aug	50	72	61	11	72	92	82	32
24-Aug	47	70	58.5	8.5	73	93	83	33
25-Aug	54	75	64.5	14.5	72	91	81.5	31.5
26-Aug	58	89	73.5	23.5	73	91	82	32
27-Aug	51	66	58.5	8.5	73	89	81	31
28-Aug	47	64	55.5	5.5	74	92	83	33
29-Aug	49	73	61	11	74	92	83	33
30-Aug	57	79	68	18	73	93	83	33
31-Aug	60	84	72	22	73	86	79.5	29.5
1-Sep	59	87	73	23	73	80	76.5	26.5
2-Sep	57	75	66	16	72	82	77	27
3-Sep	54	88	71	21	70	87	78.5	28.5
4-Sep	56	83	69.5	19.5	67	93	80	30
5-Sep	56	93	74.5	24.5	68	91	79.5	29.5
6-Sep	57	71	64	14	66	88	77	27
7-Sep	45	67	56	6	71	87	79	29
8-Sep	36	53	44.5	0	65	88	76.5	26.5
9-Sep	39	64	51.5	1.5	62	89	75.5	25.5
10-Sep	41	70	55.5	5.5	62	91	76.5	26.5
11-Sep	33	55	44	0	71	93	82	32
12-Sep	45	68	56.5	6.5	72	90	81	31

Met MN (2106)

## Review/Summary

Discuss the conclusion questions found on Handout A.

## Modifications/Extensions

Experiment with plants that have dormancy requirements. Get an assortment of spring flowering

bulbs including tulips, daffodils, crocus, and hyacinth. Force the bulbs to bloom out of season by using a refrigerator to apply a cold treatment. For more information, read the “Forcing Bulbs for Indoor Beauty in Winter” article from the University of Minnesota Extension found at <http://www.extension.umn.edu/distribution/horticulture/dg1116.html>.

### Sources/Credits

Adapted from: *Curriculum for Agricultural Science Education (2012) Principles of Agricultural Science – Plant*. [Curriculum materials for secondary agricultural education instruction]. Lexington, KY.

# Degrees of Growth

## Environmental Temperature Variations

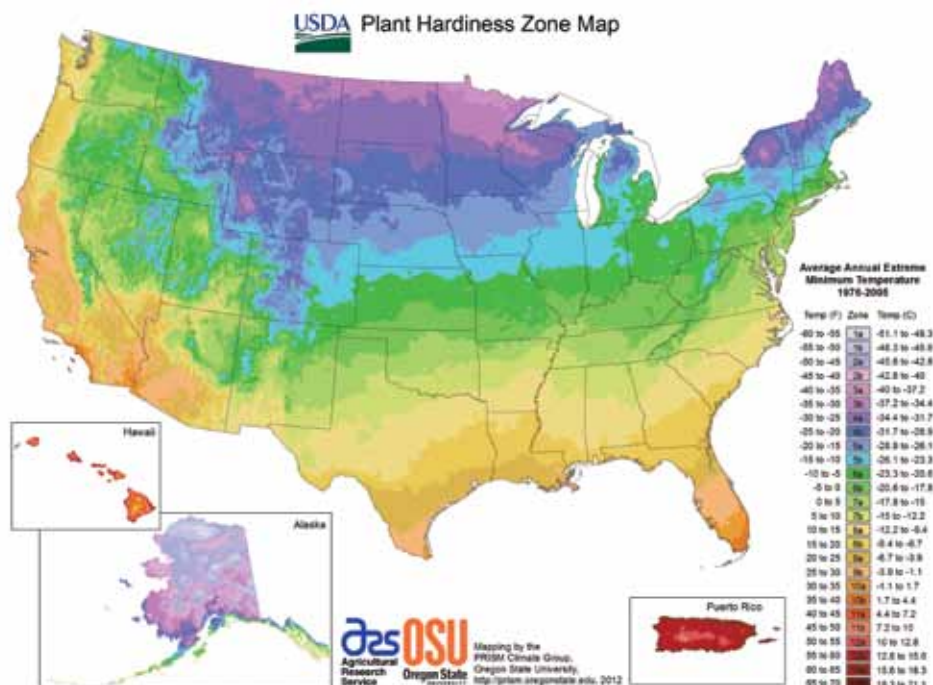
The climate, specifically temperature, for a geographic location is influenced by:

- Latitude
- Elevation
- Microclimate zones, such as coastal areas

## Hardiness Zones

A hardiness zone map provides information related to temperature ranges of geographic regions. This information is used to determine the species and varieties of plants best suited for an area.

Source: <http://www.usna.usda.gov/Hardzone/ushzmap.html>



## Temperature Sensitive

Some plants are sensitive to freezing temperatures (Examples: eggplants, peppers, and tomatoes)

Other plants require cold temperatures for adequate growth or dormancy requirements (Examples: crocus, daffodils, and tulips)

Plants have different growth requirements to reach maturity based on the length of time exposed to warm temperatures (example: watermelon need 70-90 days to grow to maturity and do best with temperatures reaching 80 degrees during the day)

## Temperature Classifications

**Plants may be classified into two general categories based on temperature requirements.**

**Cool-season:** Plants that can survive mild frost and tolerate cool spring and fall temperatures (Examples: cabbage, cauliflower, broccoli, and lettuce)

**Warm-season:** Plants are typically killed by frost and require warm temperatures to thrive and grow. (Examples: eggplants, peppers, and tomatoes)

**Plants have specific temperature requirements for:**

- Vegetative growth
- Physiological development
- Dormancy

## Temperature vs. Growth

**Plant growth and temperature have a direct relationship:**

- As temperature increases, plant growth increases. (Up to a certain point at which it begins to slow.)
- As temperature decreases, plant growth decreases.
- The optimum temperature range for most plants is between 65-85 degrees Fahrenheit.

## Why is plant growth influenced by temperature?

**Temperature influences three main metabolic functions of plants:**

- Transpiration: water evaporation from leaves
- Photosynthesis: the process in which plants use energy from the sun to make food using carbon dioxide and water
- Respiration: the process of converting sugar made by plants into energy used for growth and reproduction

## Maturity Requirements

Plants require a specific amount of time exposed to a specific threshold of temperature in order to initiate flowering.

The requirement is met by accumulating Growing Degree Days (GDD).

## Growing Degree Days

Growing Degree Days (GDD) are units of exposure to adequate temperatures required for plant growth. To calculate GDD use the following formula:

$$\frac{\text{Daily High Temperature} + \text{Daily Low Temperature}}{2} - \text{Base Temperature Requirement} = \text{GDD Units}$$

## Dormancy Requirements

- Temperature is also used to initiate and break dormancy of seeds and vegetative growth for perennial and biennial plants.
- Plants sense natural seasonal changes in temperature to initiate growth responses.

## Terms Related to Dormancy Associated with Temperature

**Forcing** is controlling temperature to promote vegetative growth and flowering outside of natural seasonal patterns in plants. (Example: forsythia stems brought indoors in March and forced to bloom early)

**Stratification** is the duration of exposure to cold temperatures to promote germination of some seed types. (Example: morning glory seeds)

**Vernalization** is the cold treatment applied to plants to initiate flowering. (Example: tulips growing in a pot indoors earlier than normal)

### References

United States National Arboretum. (2003). "Web version" of the USDA plant hardiness zone map. Retrieved December 12, 2008 from <http://www.usna.usda.gov/Hardzone/ushzmap.html>

Parker, R. (2010). *Plant and soil science: Fundamentals and applications*. Clifton Park, NY: Delmar.



Name \_\_\_\_\_



# Comparing Growth Locations

## Procedure

In this activity, you will examine two different geographic locations and calculate when fruit will be ready for harvest in both areas. You will assume tomato plants are planted on May 1 for each location. The total number of accumulated GDD units for tomatoes to reach maturity and set fruit is 2100 units. Use the temperature data in Table 1 to determine the approximate harvest date for each geographic location.

Tomatoes require a base temperature of 50 degrees for growth. Subtract the base temperature of 50 degrees from the average temperature provided for each day and record this value in the "Daily GDD" column. In the "Acc GDD" column for each location, keep a running total of the accumulated GDD units until you reach the 2100 threshold. The first three dates for each column have been done for you. Highlight the date when each location reaches 2100 GDD units.

$$\frac{\text{Daily High Temperature} + \text{Daily Low Temperature}}{2} - \text{Base Temperature Requirement} = \text{GDD Units}$$

**Table 1. Comparison Temperature Data**

**Crookston, MN**

**Plains, GA**

Date	Min	Max	Daily GDD	Acc GDD	Min	Max	Daily GDD	Acc GDD
1-May	32	65	0	0	56	91	23.5	23.5
2-May	44	69	6.5	6.5	63	88	25.5	49
3-May	54	77	15.5	22	59	89	24	73
4-May	49	55			62	87		
5-May	51	60			68	89		
6-May	51	68			64	81		
7-May	45	72			52	74		
8-May	46	80			49	83		
9-May	56	84			60	83		
10-May	41	68			61	88		
11-May	43	63			64	90		
12-May	45	75			64	90		
13-May	57	84			65	89		
14-May	40	70			66	84		
15-May	36	68			58	86		
16-May	36	63			63	86		
17-May	57	74			63	83		

# Table 1. Comparison Temperature Data

Crookston, MN

Plains, GA

Date	Min	Max	Daily GDD	Acc GDD	Min	Max	Daily GDD	Acc GDD
18-May	43	86			57	82		
19-May	41	58			56	80		
20-May	45	63			48	86		
21-May	52	80			52	90		
22-May	54	78				88		
23-May	44	72				86		
24-May	33	51				86		
25-May	43	53				87		
26-May	36	52				87		
27-May	44	66				85		
28-May	58	85				87		
29-May	53	80				89		
30-May	53	75				90		
31-May	54	75				88		
1-Jun	60	74				84		
2-Jun	59	78				74		
3-Jun	57	81				89		
4-Jun	40	71				91		
5-Jun	48	70				89		
6-Jun	57	70				91		
7-Jun	44	70				92		
8-Jun	52	74				96		
9-Jun	58	79				96		
10-Jun	67	86				97		
11-Jun	72	90				94		
12-Jun	65	89				85		
13-Jun	64	71				86		
14-Jun	63	73				86		
15-Jun	52	72				85		
16-Jun	61	80				89		
17-Jun	63	84				95		
18-Jun	52	72				94		
19-Jun	57	74				83		
20-Jun	54	78				90		
21-Jun	56	83				89		
22-Jun	64	85				93		
23-Jun	69	91				97		
24-Jun	70	87				95		

# Table 1. Comparison Temperature Data

Crookston, MN

Plains, GA

Date	Min	Max	Daily GDD	Acc GDD	Min	Max	Daily GDD	Acc GDD
25-Jun	65	89				93		
26-Jun	54	79				91		
27-Jun	54	63				93		
28-Jun	47	70				95		
29-Jun	57	75				95		
30-Jun	65	82				94		
1-Jul	66	81				96		
2-Jul	58	87				86		
3-Jul	61	85				81		
4-Jul	57	87				86		
5-Jul	53	82				88		
6-Jul	65	86				92		
7-Jul	64	95				88		
8-Jul	57	80				86		
9-Jul	56	79				91		
10-Jul	50	71				93		
11-Jul	52	73				92		
12-Jul	49	75				92		
13-Jul	56	82				93		
14-Jul	52	76				88		
15-Jul	58	71				86		
16-Jul	59	78				90		
17-Jul	60	84				91		
18-Jul	55	85				92		
19-Jul	48	77				93		
20-Jul	59	81				95		
21-Jul	65	85				90		
22-Jul	66	88				88		
23-Jul	71	95				87		
24-Jul	73	89				88		
25-Jul	69	94				89		
26-Jul	56	83				93		
27-Jul	52	81				93		
28-Jul	52	86				95		
29-Jul	66	91				93		
30-Jul	69	90				93		
31-Jul	68	92				91		
1-Aug	58	83				93		

# Table 1. Comparison Temperature Data

Crookston, MN

Plains, GA

Date	Min	Max	Daily GDD	Acc GDD	Min	Max	Daily GDD	Acc GDD
2-Aug	49	82				93		
3-Aug	58	83				93		
4-Aug	62	81				97		
5-Aug	51	85				96		
6-Aug	58	75				97		
7-Aug	60	82				100		
8-Aug	57	76				101		
9-Aug	64	88				99		
10-Aug	64	89				100		
11-Aug	48	86				103		
12-Aug	54	73				93		
13-Aug	56	74				95		
14-Aug	53	75				98		
15-Aug	46	80				99		
16-Aug	41	75				98		
17-Aug	49	72				98		
18-Aug	53	74				93		
19-Aug	56	71				94		
20-Aug	58	65				95		
21-Aug	58	77				99		
22-Aug	49	85				102		
23-Aug	50	72				92		
24-Aug	47	70				93		
25-Aug	54	75				91		
26-Aug	58	89				91		
27-Aug	51	66				89		
28-Aug	47	64				92		
29-Aug	49	73				92		
30-Aug	57	79				93		
31-Aug	60	84				86		
1-Sep	59	87				80		
2-Sep	57	75				82		
3-Sep	54	88				87		
4-Sep	56	83				93		
5-Sep	56	93				91		
6-Sep	57	71				88		
7-Sep	45	67				87		
8-Sep	36	53				88		
9-Sep	39	64				89		

# Table 1. Comparison Temperature Data

Crookston, MN

Plains, GA

Date	Min	Max	Daily GDD	Acc GDD	Min	Max	Daily GDD	Acc GDD
10-Sep	41	70				91		
11-Sep	33	55				93		
12-Sep	45	68				90		
13-Sep	32	54				89		
14-Sep	34	55				87		
15-Sep	36	68				87		
16-Sep	45	76				87		
17-Sep	53	73				83		
18-Sep	46	64				83		
19-Sep	48	65				82		
20-Sep	52	62				76		
21-Sep	42	64				80		
22-Sep	44	78				87		
23-Sep	62	91				88		
24-Sep	45	68				91		
25-Sep	43	57				89		
26-Sep	39	64				89		
27-Sep	33	65				86		
28-Sep	40	70				87		
29-Sep	55	80				84		
30-Sep	36	65				81		



## Conclusion

1. How would the different harvest dates between Crookston, MN and Plains, GA be used to an advantage for marketing tomato crops?

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2. Tomatoes typically produce their fruit over a period of several weeks to a month. Based on this information, what do you think will happen to the length of production time for tomato plants in Crookston, MN?

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3. If someone asks why a crop such as cotton is only grown in the southern U.S., how would you explain it based on what has been learned in this activity?

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4. What would happen to plant growth on a day with plenty of GDD units, but a lack of water? List the growth requirements for a plant and explain why meeting all but one of the requirements is not adequate for plant growth.

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Name \_\_\_\_\_



# Comparing Growing Locations

1. Define growing degree days.

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2. How does climate and temperature influence where crops are grown in the United States?

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3. Describe the difference between cool-season and warm-season crops.

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4. Explain the relationship between temperature and plant growth.

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